

# Table of Contents

List of Exhibits.....	4
Glossary of terms used in the report.....	9
Executive Summary.....	10
1. Introducing floating wind farms.....	16
2. Technical drivers.....	27
3. Floating Wind vessel drivers.....	40
4. What vessel designs are being considered for floating wind projects?.....	108
5. Indicative costs for building a floating wind farm.....	126
6. The Global Offshore Wind Forecast.....	137
7. UK.....	142
8. Norway.....	172
9. The European Union.....	186
10. East Asia Pacific.....	208
11. The USA and Canada.....	234
12. Other markets to watch.....	253
13. Turning the forecast into vessel supply and demand.....	257
14. Two topics to reflect on – crewing and emissions.....	278
References.....	290

## List of Exhibits

Exhibit 1 Building a floating wind farm.....	16
Exhibit 2 Main floating wind concepts.....	17
Exhibit 3 multi-turbine pilot and pre-commercial floating projects - general.....	18
Exhibit 4 Hywind Tampen turbine installation.....	19
Exhibit 5 Typical mooring arrangements.....	20
Exhibit 6 multi-turbine pilot and pre-commercial floating projects - mooring.....	20
Exhibit 7 Floating wind ports.....	22
Exhibit 8 Possible contracting package options for a floating wind project.....	23
Exhibit 9 Global technical offshore wind capacity.....	27
Exhibit 10 Average bottom-fixed wind farm sizes.....	28
Exhibit 11 Average bottom-fixed turbine output.....	29
Exhibit 12 Average bottom-fixed turbine output.....	29
Exhibit 13 Bottom-fixed turbine output by region.....	30
Exhibit 14 Floating wind turbine output by regional grouping.....	31
Exhibit 15 Global wind turbine size evolution.....	32
Exhibit 16 Western turbine hub heights.....	33
Exhibit 17 Nacelle weights of 15-16 MW turbines.....	33
Exhibit 18 Global bottom-fixed sites.....	37
Exhibit 19 Water depth of bottom-fixed wind farms.....	38
Exhibit 20 Water depth of floating wind farms.....	38
Exhibit 21 Floating wind sites - water depths.....	39
Exhibit 22 Summary of floating wind farm activities and main vessels.....	40
Exhibit 23 Typical mooring systems.....	41
Exhibit 24 Mooring pre-lay, towing and hook-up process.....	42
Exhibit 25 Mooring volumes.....	43
Exhibit 26 Global Drilling Fleet.....	44
Exhibit 27 Global semi-submersible drilling units.....	44
Exhibit 28 Global semi-submersible drilling units.....	45
Exhibit 29 Semi-submersible drilling rig tow.....	46
Exhibit 30 Floating production units (operational and on order).....	46
Exhibit 31 Floating production units - anchor systems.....	47
Exhibit 32 Floating production units - mooring line.....	47
Exhibit 33 <i>Johan Castberg</i> FPSO and planned field layout.....	49
Exhibit 34 <i>Johan Castberg</i> tow.....	49
Exhibit 35 <i>Fairplayer</i> mobilizing for mooring line installation in Brazil.....	53
Exhibit 36 Introducing mooring system components.....	55
Exhibit 37 Typical mooring points.....	56
Exhibit 38 Multi-turbine pilot and pre-commercial floating projects - anchors.....	57
Exhibit 39 Anchor characteristics.....	58
Exhibit 40 Drag embedment anchor sizes and proof loading requirements.....	59
Exhibit 41 Large AHTS bollard pull and installed power.....	61
Exhibit 42 Damen FLOW-SV vessel design.....	62
Exhibit 43 Highest winch capacity of large anchor handlers.....	63
Exhibit 44 Crane capacity of large subsea vessels.....	63
Exhibit 45 Drag embedment anchor proof loading options.....	64
Exhibit 46 Hywind Tampen mutualized anchors.....	67
Exhibit 47 Sample ScotWind floating turbine array.....	68
Exhibit 48 Chain locker input data.....	70

Exhibit 49 Potential modifications to AHTS <i>Normand Drott</i> .....	72
Exhibit 50 Potential modifications to AHTS <i>Normand Drott</i> .....	73
Exhibit 51 Mooring volumes.....	74
Exhibit 52 Large AHTS segment chain locker sizes.....	75
Exhibit 53 Chain locker capacity by various chain sizes.....	76
Exhibit 54 AHTS fleet and Hywind Tampen mooring chain.....	76
Exhibit 55 AHTS fleet and DC07 SctoWind scenario.....	77
Exhibit 56 Mooring volumes for three DC07 cases.....	77
Exhibit 57 Properties of fiber ropes and steel wire.....	80
Exhibit 58 Properties of polyester ropes.....	81
Exhibit 58 Properties of fiber ropes and steel wire.....	81
Exhibit 60 Secondary winches on the <i>Maersk Mariner</i> .....	82
Exhibit 61 Winch capacity for 203 millimeters fiber rope for selected vessels.....	83
Exhibit 62 Mooring line installation by HLV <i>Fairplayer</i> .....	84
Exhibit 63 Back deck capabilities of large anchor handler and subsea fleets.....	85
Exhibit 64 Anchors carried on an 800 square meter deck.....	86
Exhibit 65 Number of trips by deck size and number of project anchors.....	86
Exhibit 66 Required continuous rated lead tug bollard pull.....	88
Exhibit 67 Large AHTS segment by registry.....	88
Exhibit 68 Required continuous rated dual lead tug bollard pull per tug.....	89
Exhibit 69 Towing Vessels for floating wind projects.....	89
Exhibit 70 Multi-turbine pilot and pre-commercial floating projects - vessels.....	90
Exhibit 71 DC07 Base Case installation vessel spread.....	91
Exhibit 72 Assumed ScotWind Project Floating Wind Installation Vessel Operability.....	92
Exhibit 73 Dynamic floating wind array cables.....	92
Exhibit 74 Multi-turbine pilot and pre-commercial floating projects - array cables.....	93
Exhibit 75 Array cable installation from a subsea vessel.....	94
Exhibit 76 Array cable installation from a subsea vessel.....	94
Exhibit 77 Components in a 500 MW UK floating wind dynamic cable system.....	96
Exhibit 78 Base case installation vessel spread.....	98
Exhibit 75 Floating substation.....	99
Exhibit 80 Base Case installation vessel spread.....	101
Exhibit 81 Future Case installation vessel spread.....	102
Exhibit 82 Illustrative timeline for 1 GW floating wind farm installation.....	102
Exhibit 83 Estimate of vessel days for 1 GW floating wind farm installation.....	103
Exhibit 84 Tow-to-port major component exchange schedule estimate.....	104
Exhibit 85 Main floating wind project construction vessel requirements.....	108
Exhibit 86 The large anchor handler, OCV and subsea vessel segment (deck).....	109
Exhibit 87 The large anchor handler, OCV and subsea vessel segment (age).....	110
Exhibit 88 Global 300 tonnes bollard pull anchor handler fleet.....	111
Exhibit 89 Global 300 tonnes bollard pull anchor handler chain lockers.....	112
Exhibit 90 Rating of the large anchor handling fleet.....	113
Exhibit 91 400 tonnes AHC crane subsea vessel deliveries.....	116
Exhibit 88 Global large subsea vessel fleet by AHC crane size.....	116
Exhibit 93 Damen Flow-SV.....	118
Exhibit 94 Ulstein large anchor handler and subsea range.....	119
Exhibit 95 Ulstein AX141 anchor handler/OCV.....	119
Exhibit 96 Floating wind project revenue.....	120
Exhibit 97 North Sea spot and term anchor handler rates.....	124
Exhibit 98 Global WIND LCOE Projections.....	126

Exhibit 99 Global WIND LCOE Projections.....	127
Exhibit 100 Global bottom-fixed wind LCOE Projections.....	127
Exhibit 101 Floating wind project revenue.....	128
Exhibit 102 UK floating wind project CAPEX.....	129
Exhibit 103 UK floating wind project lifetime cost.....	130
Exhibit 104 UK floating wind project lifetime cost.....	130
Exhibit 105 UK floating wind project lifetime cost.....	131
Exhibit 106 California floating wind LCOE scenarios.....	132
Exhibit 107 U.S. floating wind CAPEX scenarios.....	132
Exhibit 108 California floating wind CAPEX scenarios.....	133
Exhibit 109 California floating wind CAPEX scenarios.....	133
Exhibit 110 U.S. floating wind project CAPEX (Pacific Coast).....	134
Exhibit 111 U.S. Pacific Coast floating wind project lifetime cost.....	135
Exhibit 112 Fukushima FORWARD project CAPEX.....	135
Exhibit 113 Japanese floating wind project installation costs.....	136
Exhibit 114 Global offshore wind forecast.....	137
Exhibit 115 European floating wind forecast.....	138
Exhibit 116 European floating wind forecast.....	138
Exhibit 117 Global floating wind capacity forecast by Country.....	139
Exhibit 118 Hywind Scotland.....	143
Exhibit 119 Hywind Scotland turbine installation.....	143
Exhibit 120 Hywind Scotland mooring lines.....	144
Exhibit 121 CTV at Hywind Scotland.....	145
Exhibit 122 Hywind Scotland Main Component Exchange tow-to-port AHTSs.....	146
Exhibit 123 Kincardine demonstrator mooring pre-lay.....	147
Exhibit 124 Kincardine wet tow of turbine.....	148
Exhibit 125 Kincardine Kin-03 tow-to-port maintenance schedule.....	149
Exhibit 126 UK leasing capacity and CfDs.....	151
Exhibit 127 UK leasing capacity and CfDs.....	152
Exhibit 128 INTOG floating wind sites.....	156
Exhibit 129 Culzean INTOG floating wind indicated vessel spread.....	158
Exhibit 130 Location of ScotWind sites.....	160
Exhibit 131 ScotWind floating wind sites.....	161
Exhibit 132 Celtic Sea floating wind test and demonstration sites.....	163
Exhibit 129 Round 5 Celtic Sea sites.....	164
Exhibit 134 UK Floating wind pipeline by COD.....	165
Exhibit 135 Stromar floating wind project indicative schedule.....	166
Exhibit 136 Floating wind pipeline by activity timing.....	166
Exhibit 137 Floating wind test and demonstration sites.....	167
Exhibit 138 List of potential Scottish ports suitable for floating wind projects.....	169
Exhibit 139 Potential floating wind ports.....	170
Exhibit 140 List of potential Celtic Sea ports suitable for floating wind projects.....	170
Exhibit 141 Distribution of Norway's offshore wind areas.....	172
Exhibit 142 Norway's offshore wind areas.....	173
Exhibit 143 Distribution of Norway's offshore wind areas.....	174
Exhibit 144 Location of Norway's offshore oil & gas fields.....	175
Exhibit 145 Norwegian floating wind pipeline by COD.....	178
Exhibit 146 Tetraspar mooring tensioning.....	180
Exhibit 147 Hywind Tampen array layout.....	181
Exhibit 148 Hywind Tampen array layout.....	182

Exhibit 149 Hywind Tampen towing and hook-up vessels.....	183
Exhibit 150 Hywind Tampen high-level vessel schedule.....	184
Exhibit 151 European Interconnector Market (kilometers of interconnector cable).....	187
Exhibit 152 NSEC tender planning & indicative construction schedule.....	188
Exhibit 153 France’s planning targets.....	189
Exhibit 154 French floating wind in operation and under development.....	189
Exhibit 155 Floatgen mooring.....	190
Exhibit 156 French floating wind projects and tenders.....	195
Exhibit 157 French floating wind pipeline by COD.....	196
Exhibit 158 Mediterranean floating wind pipeline by COD.....	198
Exhibit 159 DemoSATH mooring pre-lay.....	202
Exhibit 160 Portuguese floating wind pipeline by COD.....	204
Exhibit 161 Windfloat Atlantic mooring pre-lay vessel.....	205
Exhibit 162 Windfloat Atlantic towing vessel.....	206
Exhibit 163 APAC Offshore wind technical potential by water depth.....	208
Exhibit 164 South Korea’s Regional Geology and Site Conditions.....	208
Exhibit 165 South Korean auction planning.....	209
Exhibit 166 South Korean floating wind planning.....	210
Exhibit 167 South Korean floating wind pipeline by COD.....	213
Exhibit 168 Japan’s floating wind pipeline by COD.....	216
Exhibit 169 Japan’s offshore wind technical potential by water depth within the EEZ.....	217
Exhibit 170 Japan’s technical potential within 24 nautical miles from shore.....	218
Exhibit 171 Fukushima Installation Weather Windows by Crane and Winch.....	221
Exhibit 172 U.S. floating wind technical potential.....	234
Exhibit 173 California floating wind sites.....	235
Exhibit 174 California floating wind sites.....	237
Exhibit 175 California floating wind port infrastructure requirements.....	239
Exhibit 176 U.S. floating wind technical.....	241
Exhibit 177 Maine offshore wind auction detail.....	244
Exhibit 178 U.S. Floating wind pipeline by COD.....	245
Exhibit 179 Deepwater Gulf of Mexico oil & gas projects.....	245
Exhibit 180 Newfoundland and Labrador preliminary licensing areas.....	251
Exhibit 181 Nova Scotia preliminary licensing areas.....	252
Exhibit 182 Indicative planning of India’s offshore wind auctions.....	253
Exhibit 183 India Model B Tamil Nadu wind zones.....	254
Exhibit 184 Columbia’s Potential Wind Zones.....	255
Exhibit 185 Global floating wind turbine forecast.....	257
Exhibit 186 Global floating wind turbine forecast by turbine category.....	258
Exhibit 187 Global adjusted floating wind turbine forecast.....	258
Exhibit 188 Global floating wind potential installation scope spend.....	259
Exhibit 189 Regional floating wind EPCI spend.....	260
Exhibit 190 Regional floating wind EPCI spend.....	260
Exhibit 191 Base case installation vessel spread.....	261
Exhibit 192 Global anchor installation forecast.....	262
Exhibit 193 Global suction anchor vessel supply and demand forecast.....	263
Exhibit 194 Global pre-lay mooring line forecast.....	264
Exhibit 195 Global mooring chain forecast.....	265
Exhibit 196 Global fiber mooring rope forecast.....	265
Exhibit 197 Mooring line forecast – Base and Future Cases.....	266
Exhibit 198 Mooring line forecast – DEA Case.....	266

Exhibit 199 Lead towage and hook-up vessel supply & demand forecast.....	267
Exhibit 200 Towage and hook-up support vessel supply & demand forecast.....	267
Exhibit 201 Demand for 300 tonnes bollard pull anchor handlers.....	268
Exhibit 202 Demand for 300 tonnes bollard pull anchor handlers.....	268
Exhibit 203 Lead anchor handler supply & demand forecast in including O&M demand (low).....	269
Exhibit 204 Lead anchor handler supply & demand forecast in including O&M demand (high).....	270
Exhibit 205 Array cable pre-lay forecast.....	270
Exhibit 206 400t AHC vessel forecast.....	271
Exhibit 207 Large anchor handler utilization sensitivities.....	272
Exhibit 208 Large anchor handler age sensitivity.....	272
Exhibit 209 Large anchor handler age and utilization sensitivity.....	273
Exhibit 210 Large subsea vessel utilization sensitivities.....	273
Exhibit 211 Large subsea vessel age sensitivity.....	274
Exhibit 212 Large subsea vessel age and utilization sensitivities.....	274
Exhibit 213 global floating wind CSOV forecast.....	275
Exhibit 214 global floating wind CSOV utilization sensitivities.....	276
Exhibit 215 global floating wind SOV forecast.....	276
Exhibit 216 global floating wind SOV utilization sensitivities.....	277
Exhibit 217 European Union emissions reporting and carbon taxation.....	279
Exhibit 218 Energy Carrier Choices.....	280
Exhibit 219 Fuel density for the same energy content.....	281
Exhibit 220 The Methanol Production Process.....	282
Exhibit 221 Normand Sagaris fuel consumption and emissions.....	283
Exhibit 222 Anchor handler fuel consumption and emissions on a commercial wind farm.....	284
Exhibit 223 Selection of Crew Positions and Requirements.....	285
Exhibit 224 Additional key crew requirements (mutualized case).....	287
Exhibit 225 Additional key crew requirements (DEA case).....	287
Exhibit 226 Additional key crew requirements (Taut case).....	288
Exhibit 227 Global semi-submersible drilling rig segment.....	288
Exhibit 228 global floating production and storage segment.....	289

# Glossary of terms used in the report

<b>AHT/S</b>	Anchor handling tug/and supply. Vessels characterized by large winches for towing and anchor handling, an open stern for deploying and landing anchors and a large bollard pull	<b>TSO</b>	Transmission system operator
<b>SSV</b>	Subsea vessel	<b>ESO</b>	Electrical system operator
<b>CLV</b>	Cable lay vessel	<b>OFTO</b>	Independent offshore transmission owner
<b>CLB</b>	Cable lay barge	<b>O&amp;M</b>	Operations and maintenance
<b>OSV</b>	Offshore support vessel	<b>EAPAC</b>	East Asia Pacific: Australia, China, Japan, South Korea, New Zealand, and the Philippines
<b>SOV</b>	Service operations vessel	<b>Europe</b>	Norway, the UK and the European Union (Belgium, Croatia, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Malta, Luxembourg, the Netherlands, Poland, Portugal, Spain, and Sweden)
<b>CSOV</b>	Commissioning service operations vessels	<b>EU</b>	European Union
<b>CTV</b>	Crew transfer vessel	<b>EEA</b>	EU plus Iceland, Liechtenstein and Norway
<b>BP</b>	Bollard pull	<b>NAM</b>	North America: Canada and the United States of America
<b>AHC</b>	Active heave compensated	<b>SAM</b>	South America: Brazil and Columbia
<b>DP</b>	Dynamic positioning	<b>ISC</b>	Indian subcontinent
<b>mm</b>	Millimeters	<b>MSP</b>	Maritime Spatial Planning, an EU platform to share information and coordinate planning
<b>m</b>	Meters (1,000 millimeters)	<b>NSEC</b>	The North Seas Energy Cooperation, which supports the development of offshore renewables and the required offshore grid infrastructure in the wider North Sea area
<b>km</b>	Kilometers (1,000 meters)	<b>North Seas</b>	North Sea, the Irish Sea, the Celtic Sea, the English Channel and neighboring waters
<b>kW</b>	Kilowatt (1,000 watts)	<b>BEMIP</b>	The Baltic Energy Markey Interconnection Plan aims to facilitate interconnection and integrated regional planning within the wider Baltic region
<b>MW</b>	Megawatt (1,000 kW)		
<b>GW</b>	Gigawatt (1,000 MW)		
<b>TW</b>	Terawatt (1,000 GW)		
<b>kV</b>	Kilovolts		
<b>kWh</b>	Kilowatt hour		
<b>AC</b>	Alternating current		
<b>DC</b>	Direct current		
<b>HVAC</b>	High voltage alternating current		
<b>HVDC</b>	High voltage direct current		
<b>TLP</b>	Tension leg platform		
<b>COD</b>	Commercial operations date, which occurs on completion of the commissioning of all systems on the wind farm and operations officially commence		
<b>CfD</b>	Contracts for difference		